

Title: METHOD FOR REGULATING THE OPERATING FREQUENCY AND  
MULTIFUNCTIONAL INTEGRATED CIRCUIT CHIP OF A FIBER  
OPTIC GYROSCOPE

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BACKGROUND

Field of The Invention

10           The present invention relates to fiber optic  
gyroscopes (FOGs). More particularly, this invention  
pertains to a method and apparatus for regulating the  
operating frequency of a closed loop FOG. ~~The invention~~  
~~relates to a method for regulating the operating frequency~~  
15 ~~of a fiber-optic gyroscope (FOG) with a closed control loop,~~  
~~in which the demodulated output signal of the FOG detector,~~  
~~as actual signal, is applied on the one hand to the input of~~  
~~an FOG main controller and on the other hand, via a gating~~  
~~filter, to a VCO that determines the system clock of the~~  
20 ~~FOG, the output signal of the main controller, as modulation~~  
~~signal, being fed to a digital phase modulator formed in a~~  
~~multifunctional optical chip (MIOC), and, for the purpose of~~  
~~determining and regulating the exact operating frequency of~~  
~~the FOG, a periodic additional modulation signal is~~  
25 ~~superposed on the demodulated detector output signal passing~~  
~~to the gating filter. The invention additionally relates to~~  
~~a multifunctional integrated optical chip (MIOC) for a~~  
~~fiber-optic gyroscope (FOG).~~

### Description of the Prior Art

German patent DE 197 53 427 C1 describes a digital phase modulator, ~~in particular~~ for closed loop fiber optic rate-of-rotation sensors ~~with a closed loop~~, in which, ~~in~~  
5 ~~order~~ the less significant portion of a binary drive signal supplied by an FOG main controller is converted into an analog signal by means of a ~~having a~~ relatively low resolution digital/analog converter to increase ~~the~~ resolution, ~~which~~ . The analog signal is fed to a ~~further~~  
10 dedicated electrode ~~that is provided separately~~ on the integrated optical chip containing the digital phase modulator. ~~The~~ Resolution can thus be increased e.g. from 8 to approximately 10 bits. The separate dedicated electrode (or, if appropriate, a separate electrode pair) is assigned  
15 directly to the digital phase modulator.

German patent application 101 30 159.6, ~~not published before the priority date~~, ~~proposes~~ discloses a method for avoiding bias errors ~~on account of~~ due to  
20 synchronous interference in closed loop fiber-optic gyroscopes ~~with a closed control loop~~, ~~which provides for~~ by superposing a signal on the demodulated output signal of the FOG detector ~~which~~ . Such signal is periodic at the sampling clock rate of the FOG and is applied in the form of ~~an added~~  
25 a modulation that is added at the digital phase modulator of a multifunctional integrated optical chip. The ~~remainders~~

residue of ~~this additional~~ the added modulation ~~that are~~  
present in the demodulated detector signal ~~are~~ is detected  
and fed to an auxiliary control loop ~~which that~~ readjusts  
the operating frequency so that the ~~additional~~ added  
5 modulation tends toward zero as ~~far~~ much as possible.

~~However, the Implementation of this known~~ the  
above method (through the use of a mixed drive signal at the  
phase modulator of the MIOC), which ~~leads to a considerable~~  
10 ~~increase in~~ considerably increases the accuracy of FOGs, has  
led, in practice to ~~practical~~ difficulties. Such  
difficulties relate, in particular, to a conflict of  
objectives when it is simultaneously attempted to solve ~~the~~  
~~resolution of the~~ digital phase modulator, resolution  
15 without increasing the structural length of the MIOC,  
~~differently~~ other than is described in the abovementioned  
German patent specification. This is particularly true when  
the phase modulator is intended to be operated with non-  
binary drive signals ~~for increasing~~ to increase resolution.

20

~~The invention is thus based on the object of~~  
~~simplifying the method for regulating the operating~~  
~~frequency of an FOG.~~

25

## SUMMARY AND OBJECTS OF THE INVENTION

It is therefore an object of the invention to simplify the regulation of FOG operating frequency.

5           In a first aspect, the invention provides a method for regulating the operating frequency of a fiber optic gyroscope with a closed control loop. The demodulated output signal of the FOG detector, as actual signal, is applied on the one hand to the input of a FOG main  
10 controller and, on the other hand, via a gating filter to a VCO that determines the system clock of the FOG. The output signal of the main controller, as modulation signal, is fed to a digital phase modulator formed in a multifunctional integrated optical chip and, for determining and regulating  
15 the exact operating frequency of the FOG, a periodic additional modulation signal is superposed on the demodulated detector output signal passing to the gating filter.

20           Such method is characterized in that the additional modulation signal, as analog signal, is fed to separate phase correction electrodes in the multifunctional integrated optical chip.

25           In a second aspect, the invention provides a multifunctional integrated optical chip for a fiber optic

gyroscope in which a phase modulator realized by electrodes arranged parallel to a light guiding path is implemented as at least one functional group.

5           Such multifunctional integrated optical chip is characterized in that, in addition to the phase modulator, an electrode pair arranged parallel to the light guiding path is present for applying a periodic additional modulation signal to a light beam on the light guiding path  
10 for the purpose of regulating the operation frequency of the gyroscope.

The preceding and other features of the invention will be apparent from the detailed description  
15 that follows. Such description is accompanied by a set of drawing figures. Numerals of the drawings, corresponding to those of the written description, point to the features of the invention with like numerals referring to like features throughout.

20

~~The invention and advantageous details are explained in more detail below in an exemplary embodiment with reference to the drawings in which:~~

#### BRIEF DESCRIPTION OF THE DRAWINGS

25           Figure 1 ~~shows~~ is a schematic block diagram of the architecture of ~~an a~~ FOG with ~~illustration of the operating~~

frequency regulation ~~according to~~ in accordance with the invention; and

Figure 2 ~~shows is~~ a somewhat simplified illustration, ~~the~~ plan view of a  
5 multifunctional integrated optical chip (MIOC) ~~with additional electrodes~~ for advantageously realizing the frequency regulating method ~~according to~~ of the invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

10 Figure 1 is a schematic block diagram of the architecture of a FOG 100 with operating frequency regulation in accordance with the invention. ~~The optical architecture of a fiber-optic gyroscope is assumed to be known in principle; therefore, it is only illustrated as~~  
15 ~~block 100 in figure 1.~~ The A measurement signal ~~which is~~ supplied by the detector 10 of the FOG 100 ~~and~~ contains the rate-of-rotation information. Such signal is demodulated by ~~an~~ a FOG demodulator 13 and, ~~since as~~ a fiber optic gyroscope with a closed control loop is involved, it is  
20 applied to the input of ~~an~~ a FOG main controller 14, ~~which~~

Figure 2 is a simplified plan view of a multifunctional integrated optical chip (MIOC) 11 for realizing the frequency regulating method of the invention.  
25 Referring to both Figures 1 and 2, the FOG main controller 14, inter alia, supplies a preferably non-binary  $U_n$ , or

resetting signal, at its output side to a digital phase modulator 24, ~~which that~~ is formed in ~~a multifunctional integrated optical chip, i.e. an the~~ MIOC 11, ~~and in mirror-symmetrical embodiment, In mirror-image,~~ in a manner  
5 known in ~~principle theory, this~~ influences the light beams on two light guiding paths L1, L2, ~~which light beams have been~~ produced after a beam splitting at 23 and ~~pass~~ passing through a measuring coil (not shown) in opposite directions. ~~(c.f. figure 2).~~

10

In addition to the FOG demodulator 13 and the FOG main controller 14, an additional modulation device 15 is ~~present~~ provided, the periodic output signal  $\phi E$  of which is ~~on the one hand~~ superposed on the modulation signal from the  
15 FOG main controller and ~~then~~ controls, via a gating filter 20, a voltage-controllable oscillator (VCO) 12 that ~~determines~~ provides the operating clock of the FOG gyroscope system.

20

According to the invention, the additional modulation signal  $\phi E$  passes to an analog section ~~which is~~ formed in the MIOC 11 and, as ~~shown~~ best illustrated in Figure 2, is realized by an additional electrode pair 25 that is ~~independent of~~ separate from the digital phase  
25 modulator 24. The additional modulator signal  $\phi E$  ~~having~~ has relatively small amplitude, ~~which signal and~~ is periodic at

the sampling clock rate. It is thus passed to the additional electrode, or the electrode pair 25 in the example illustrated in Figure 2, and typically, ~~but in no way restrictively not exclusively,~~ produces a maximum phase shift of  $\pi/32$ . This phase shift is sufficient to generate, after demodulation, a signal ~~which~~ that controls the VCO 12 via the gating filter 20 in such a way that the desired operating frequency of the FOG system is ~~complied with exactly~~ precisely accomplished. In a ~~departure from~~ contrast to the solution described in German patent application 101 30 159.6, ~~not published before the priority date,~~ the periodic additional modulation signal  $\phi E_7$  for determining ~~the~~ gyroscope frequency, is not added to the digital MIOC modulation signal, ~~but~~ Rather, it is passed directly to the additional analog electrode or the electrode pair 25, ~~that is to say (i.e.,~~ to the analog section 22 of the MIOC 11.)

~~The~~ A particular advantage of the invention is that the additional modulation signal  $\phi E$  ~~does not have to needn't~~ be digitally converted, ~~and an~~ obviating the addition of a modulation signal and additional modulation is ~~obviated~~. Rather, a periodic additional signal for determining the frequency or regulating the frequency of the FOG, as analog signal, is fed to separated phase correction electrodes formed in the MIOC.

In the case of a method of the generic type mentioned in the background, simplification of regulation of the operating frequency of a FOG ~~introduction, this object~~ is achieved according to the invention by virtue of the fact  
5 that a periodic additional signal for determining the frequency or regulating the frequency of the FOG, as analog signal, is fed to separate phase correction electrodes formed in the MIOC.

10           ~~The MIOC A multifunctional integrated optical chip~~  
~~(MIOC) for a fiber-optic gyroscope, FOG~~ in which a phase modulator is realized by electrodes arranged parallel to a light guiding path is implemented as at least one functional group. It is suitable for realizing the method ~~according to~~  
15 ~~of the invention by virtue of the fact that as,~~ according to the invention, in addition to the phase modulator, an electrode pair arranged parallel to the light guiding path is present for applying a periodic additional modulation signal to a light beam on the light guiding path ~~for the~~  
20 ~~purpose of regulating~~ to regulate the operation frequency of the gyroscope.

An optimized structural size of the integrated optical chip can be achieved when the additional electrode  
25 pair is arranged between the digital phase modulator and a beam splitter within the chip.

While the invention has been described with  
reference to its presently preferred embodiment, it is not  
limited thereto. Rather, the invention is limited only  
insofar as it is defined by the following set of patent  
5 claims and includes within its scope all equivalents  
thereof.

What is claimed is:

1                    1.    A method for regulating the operating  
2 frequency of a fiber optic gyroscope ~~(FOG)~~ with a closed  
3 control loop, in which the demodulated output signal of the  
4 FOG detector, as actual signal, is applied on the one hand  
5 to the input of an FOG main controller and on the other  
6 hand, via a gating filter, to a VCO that determines the  
7 system clock of the FOG, the output signal of the main  
8 controller, as modulation signal, being fed to a digital  
9 phase modulator formed in a multifunctional integrated  
10 optical chip ~~(MIOC)~~, and, for the purpose of determining and  
11 regulating the exact operating frequency of the FOG, a  
12 periodic additional modulation signal is superposed on the  
13 demodulated detector output signal passing to the gating  
14 filter, characterized in that the additional modulation  
15 signal, as analog signal, is fed to separate phase  
16 correction electrodes formed in the ~~MIOC~~ multifunctional  
17 integrated optical chip.

1                   2.    A multifunctional integrated optical chip  
2 ~~(MIOC-11)~~ for a fiber optic gyroscope ~~(FOG-100)~~ in which a  
3 phase modulator ~~(21)~~ realized by electrodes arranged  
4 parallel to a light guiding path is implemented as at least  
5 one functional group, characterized in that, in addition to  
6 the phase modulator, an electrode pair ~~(25)~~ arranged  
7 parallel to the light guiding path is present for applying a  
8 periodic additional modulation signal ~~(OE)~~ to a light beam  
9 on the light guiding path for the purpose of regulating the  
10 operation frequency of the gyroscope.

1                   3.    The integrated optical chip as claimed in  
2 Claim 2, characterized in that the additional electrode pair  
3 is arranged between the phase modulator and a beam splitter  
4 ~~(23)~~.

# ABSTRACT

A ~~In the~~ method for regulating the operating frequency of a closed loop fiber optic gyroscope ~~(FOG-100)~~ ~~with a closed control loop in which~~ . The demodulated output signal of ~~the FOG~~ a detector ~~(10)~~, as actual signal, is applied ~~on the one hand~~ to the input of a ~~an FOG~~ main controller ~~(14)~~ and ~~on the other hand~~, via a gating filter ~~(20)~~, to a VCO ~~(12)~~ that determines the system clock of the FOG. ~~the invention provides for feeding~~ An additional modulation signal, as analog signal ~~(OE)~~ is fed to separate phase correction electrodes that are formed together with the electrodes of a digital phase modulator in an integrated optical chip ~~(MIOC-11)~~. ~~The method according to the invention and the particular configuration of the MIOC (11) enable the operating frequency of the FOG to be regulated exactly.~~